DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

PROBLEMS OF PROGRESS IN INDUSTRY—12

HUMAN SCIENCES

aid to industry

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PREFACE

This booklet has been prepared at the request of the Research Council's Human Sciences Committee, of which I am Chairman. The past decade has seen the expansion of research in the human sciences, notably in the measurement of human abilities and in the effects of social and technological factors on individual performance. We think the time has now come to appraise the overall contribution this knowledge makes to the understanding of human problems in an industrial environment. Many of the studies quoted as examples in this booklet have been described in some detail in previous issues in this series. The aim of the present issue is to review the scientific approach illustrated in these studies, and to discuss the emergence of general principles of human behaviour applicable to industrial skills and organization. We hope that this booklet will stimulate a great number of responsible people on both sides of industry to take an active interest in the future development of the human sciences, which depends not only on continued fundamental research but also on applied studies within industry. We are confident that the building up of knowledge in this field and its application to industrial problems holds promise for the greater well-being of individual men and women in their working lives, and also for the increased efficiency of our industrial effort.

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CONTENTS

Research into materials and products, processes and operations, is commonly accepted by forward looking firms in industry as essential to technical progress. There is no such unanimity, however, on research into the human factor in production: whether the man or woman is regarded as an individual worker or as a member of the industrial society. While many firms call in technical experts to advise them on some new equipment they are planning to install or on problems that arise in the operation of existing plant, comparatively few even consider the possibility of seeking expert advice on problems concerned with the men and women who operate the machines or run the plant. Yet today, with the growing insistence on self-expression by industrial labour, the importance of the human factor is certainly recognized. Increasing mechanization, although it has changed the nature of the human contribution, has by no means diminished its importance. Indeed, when machines become more complex to operate and maintain, it is often the capacity of the human operator rather than of the equipment that places the limit on the productivity of the man/machine team.

Why does only a small minority of firms recognize the value of research on human performance as an essential feature of industrial development? Is it because people consider the systematic study of human factors in industry relatively new? This can hardly be so since it was put on an official footing in this country in World War I with the establishment of the Health of Munition Workers Committee. The now classical Hawthorne studies in the USA were undertaken about thirty years ago. Is it because research workers have failed to establish by scientific methods principles of human performance which can be applied in industry? Their work in the Armed Services, and in the fields of selection and training in industry, should be enough to refute this criticism. Or is it because people in industry have little opportunity of finding out about the work of the psychologist and sociologist? They are, perhaps, unaware of how the results of research can be applied to the solution of human problems in industry and how, if applied early enough, they can help to prevent new problems arising. It is in the belief that industry suffers an

understandable lack of knowledge about these things, that DSIR has attempted to provide an information channel from the academic producer of research results to the potential user in industry.

Between the wars, the Government supported research in the human sciences mainly through the Industrial Health Research Board of the Medical Research Council, which investigated problems of human abilities, temperament and motivation, and the effects of environmental conditions and hours of work on working efficiency. During the 1939–45 War, the main work was centred in the personnel research committees of the three Armed Services, which sponsored research particularly in the fields of selection and training, and equipment design. The Services continue to support this research which, although directed primarily at Service problems, has applications to problems of men and machines in industry. At the end of the war the research programme of the Human Factors Panel of the Committee on Industrial Productivity was concerned with the human problems of industrial efficiency and expansion.

Some eight years ago responsibility for work in the fields of human relations and individual efficiency in industry was given to two joint DSIR/MRC Committees, which surveyed the progress of knowledge and research in the human sciences, advised on problems for research and sponsored new research. Their scope in sponsoring research was greatly extended when funds were made available to them under the US Conditional Aid scheme. They covered a wide range of subjects from the design of instrument controls to surveys relating organization to technology and their achievement forms an impressive testimony to the contribution that human sciences research can make to the future of industry.

With the end of the term of office of these Joint Committees, the Council for Scientific and Industrial Research appointed a Human Sciences Committee to advise on its continued and growing interest in the human sciences. More recently, DSIR has set up at its Warren Spring Laboratory a human sciences section which is responsible for the Department's research programme in the human sciences, whether carried out by its own staff or through extra-departmental contracts, and for consequential work in liaison and dissemination, which it shares

with the Information Division at the Department's Headquarters.

Obviously in a small booklet like this it is impossible to do more than sketch in lightly the outlines of research in the human sciences, from the laboratory studies of human capacities to studies of man at work and even studies of man as a member of a social group. Emphasis will be laid on the relevance of this research to the industrial situation. A few examples will be given from studies sponsored either wholly or partially by DSIR.

I. STUDIES OF HUMAN EFFICIENCY

LABORATORY STUDIES

Laboratory experiments may seem extremely remote and impractical to the busy industrialist who must find immediate answers to problems. Yet it is on carefully controlled and measured laboratory studies that any claims of the study of human behaviour to be an exact science rest, and that the scientific methods applied to human problems in industry depend for their development.

The results of laboratory studies do not depend on the personal judgements made by the research worker nor on what a man doing an experiment says about it. The use of electronic and high-speed photographic recording instruments enables the research worker to make detailed analyses not only of the final outcome of the experimental task but also of all the steps taken to complete the task. He can then collect the records of sufficiently large groups of people studied under uniform conditions and carry out statistical tests, often with the aid of an electronic computer. It is sometimes argued that statistics are meaningless when they deal with individuals whose differences often appear so great. While the human sciences cannot aim at achieving the statistical standards of the physical sciences, they can establish the ultimate limits of human capacities, and indicate how the actual capacities are distributed within this range. Seldom are the limits of capacity reached in industrial work. What is of value to know is what factors influence the shape of the distribution curve of human capacities.

In the laboratory research workers study physical capacities, such as sight, hearing, touch, taste, muscular strength; and mental capacities such as interpreting, remembering, reproducing information coming through the senses, and making decisions to act. They determine the ranges and averages for different samples of the population, based on variable factors such as sex, age, intelligence, education and occupation. They investigate the effects on physical and mental capacities of such factors as fatigue, loss of sleep, alcohol and drugs, and of environmental conditions, for example, heat, cold, noise, and levels of illumination.

Light, noise and other sensory stimuli must possess certain

characteristics before they can be observed. Laboratory studies determine not only these physical characteristics but also the degree to which two stimuli must differ to be distinguished from one another. Experiments determine the time a man takes to react to a single stimulus compared with the time he takes to select one particular stimulus from among a group. The frequency and pattern of stimuli affect both the probability that any single stimulus occurring in a series will be observed and the speed of response to it if it is perceived.

These experiments are relevant to industrial situations. Apart from the traditional inspection jobs, skill in finding faults or deviations from a standard is needed on a number of control jobs. Process operators usually have to monitor instruments and only take action at infrequent intervals if they observe a variant reading. The effects of prolonged working sessions, fatigue and boredom, on the speed and accuracy of discrimination have been studied both under laboratory conditions, using 'vigilance' tasks, and under operational conditions in the Armed Services.

Studies indicate that the human brain deals with incoming information either as single items or as groups of items received one at a time. Only a certain amount of decision-making about action can be done within a given time, and it naturally takes longer to make decisions as the choice becomes more complex. If not enough time is spent on them, errors are made. It is now possible to measure the rate at which a man is required to transmit information from the environment in order, for example, to operate a lever on the basis of what he sees on an instrument panel. It seems clear from research findings that the speed at which a man carries out a task depends on the time he takes to decide on what to do and not on the time he spends making the movements. Such work has led to recommendations on ways of reducing the complexity of a task, for example by the use of spatial groupings of instruments and dials, based on the logical flow of the tasks, and by colour coding.

Conditions affecting the ability to solve problems, to make decisions, to interpolate and extrapolate from varying amounts of material, are obviously not questions solely of academic interest, but have direct implications in industry where a firm's success depends largely on the ability of individuals to assess trends and act at the right time.

Laboratory research on the ability to learn provides principles on which training schemes can be based. Problems such as how to learn quickly, whether to tackle a task as a whole from the start or to master it in bits, how to help someone to learn, have all been studied in relation to a number of different tasks. The results have obvious applications in industry.

STUDIES OF MEN AT THEIR JOBS

Research in the human sciences has not been confined to laboratory studies. Over the last 40 years, the human problems of industrial efficiency have been tackled in the factory.

It is mainly in the field of personnel selection, of finding the right man for the job, that industry has recognized the value of expert advice. The early work in the laboratory, on the nature of intelligence and aptitudes, led to the widespread use of intelligence and aptitude tests. But studies of fatigue, length of working shifts, and effects of rest pauses, carried out before and after the 1914–18 War, also produced results that were applied in industry; and studies of working conditions resulted in standards of ventilation, heating and lighting which form the basis of factory practice today.

Selection and training

Both selection and training methods depend on a careful analysis of each job and a match between its demands and the ability of the individual. A good deal of research into the nature and organization of industrial skills has already been applied in industry.

At Birmingham University a study has been made of speed-skills exercised by semi-skilled operatives mainly in batch- and mass-production manufacturing industries, although some of the findings may also apply to continuous-process industries. Film analysis and records from specially designed apparatus were used to study the changes in the time taken for the basic elements of movement, or *therbligs*, when subjects improved in performance on industrial tasks comprising varied perceptual loads. The results indicated the need to consider the perceptual as well as the spatial requirements of therbligs in a task, since those involving most perception contributed most towards the improvement

in overall performance. It was also shown that the speed-skill on a typical industrial task was acquired more rapidly when, as a result of analysing the perceptual and mental elements, in addition to the movement patterns, the difficult elements were isolated and learned separately before they were combined. These methods of analysing the perceptual and mental elements of a task, as well as movement, can contribute to improvements in the design of equipment and in methods of work. The quantitative approach to the measurement of perceptual load based on information theory, provides a new dimension for work-measurement.

A study at Oxford University gives evidence that the experienced operator has learned to attend to fewer cues, whereas the trainee has the additional and difficult job of sorting significant from irrelevant information before he decides what is the appropriate movement to make. The results of this study emphasize that the essence of training is first to specify what responses are needed and then to remove obstructions which prevent them from being made. In some cases, for example, the trainee may be unable to detect the effective cue for a response, so that the cue must be clearly indicated to him, perhaps by the use of some additional signal. In others the trainee may be unable to respond to a new cue because he is still paying attention to a response that he is carrying out at the time or that he has just completed. In this case the obvious training procedure is to practise the required response separately and then to combine it into the task.

Sometimes the trainee may be quite capable of making the response, but has no means of knowing whether he is doing the right thing. He should then be given some knowledge of the results of his action. Whether or not extra cues should be provided, or knowledge of results given, or whether the task should be practised as a whole or divided into parts and each learnt separately before being combined, are questions which can only be answered in the context of a particular training situation. The Oxford team recommend that training should always begin with an analysis of the trainees' difficulties. By introducing a formal training scheme in which special practice is given to the more difficult parts of the task, this team has reduced the time to train carpet weavers from about 16 to 4 weeks.

The National Institute of Industrial Psychology has investigated the practical effect of certain theories when applied to training sewing machinists. It found, for example, that planned exercises in machining, designed according to psychological principles, can lead trainees directly to the skilled workers' style of performance, which is associated not only with speed but with high quality of output. In another study, the NIIP has shown that the provision of conspicuous information about day-to-day achievement of groups of trainees, in a way which permits competition to develop, may increase the amount of practice trainees will try to put in.

A study of training problems by the British Boot, Shoe and Allied Trades Research Association (SATRA) has shown the value of giving trainees some knowledge of results. By attaching to sewing machines scales indicating the number of stitches made in a minute, they helped trainees to acquire the skill of controlling the speed of the machines.

Ergonomics

The success of selection techniques, and the ability of most people to adapt themselves to most situations, however difficult, have led industry in the past to neglect the improvement of efficiency by fitting the job to the man. There is, however, an ever-increasing interest in ergonomics, which is a combined approach by psychologists, physiologists, anatomists and engineers to the human problems associated with work. The aim of this research is to develop principles of human behaviour which, when applied to the design of equipment and of the working environment, will reduce the amount of mental and physical strain, while maintaining and even improving the standard of performance.

Display problems, such as the right shape and size of dials, the spacing of scale markings, and the design of lettering for, say, reading at different distances, have been widely studied and have led to principles of good design. Studies on the shape, size, positions of knobs, levers and handles, and the direction of movement of the control in relation to the display, have similarly resulted in recommendations as to which designs of control mechanisms are most suited to particular machines.

The heights, widths and shapes of chairs, tables and work benches have been studied in great detail, and the results have already been incorporated in furniture design.

Other researches have been concerned with improving efficiency by changes in equipment design. For example, SATRA has studied the control of sewing machines and, by redesigning the foot control, has reduced the complexity of the job and raised output by about 10 per cent. A project undertaken by the Medical Research Council's Applied Psychology Research Unit has resulted in increased speed and accuracy and a reduction in training time, in the use of some machine tools. A counting device fitted to the handle of a machine tool showed the total machine setting required as a line of numerals instead of the more usual micrometer dial. A third example comes from the British Iron and Steel Research Association which has carried out laboratory and field studies of the design and layout of steel-works control points, including crane cabs, charging machines and mill pulpits, to improve the efficiency and safety of operations.

Other studies in the field of ergonomics have been concerned with the effects on working performance of such factors as time of day, the day of the week and shift systems.

Inspection

While mechanical aids and automatic techniques have been widely applied to many production processes, there has not been, mainly for technical and economic reasons, a corresponding large-scale development of sensing or other devices for the control of quality. Responsibility for picking out 'rejects' remains generally in the hands of the men and women at inspection points. Brief reference has already been made to the relevance to inspection jobs of some of the laboratory studies of physical and mental capacities. Other studies have been directly concerned with various aspects of industrial inspection.

At Edinburgh University an investigation into inconsistencies among inspectors has shown wide differences between the number of items rejected out of the same test batch of products, not only by different inspectors, but also by the same inspector on different occasions—even when gauges and meters are used to measure the products. The Edinburgh team has recommended

ways of improving accuracy, based not only on its own observations and experiments but also on the results of previous studies in this field. Better selection, adequate training, careful definition of faulty products, provision of samples of good and bad products as reference standards, objective tests to check individual accuracy, and spells of refresher training—all these are ways of improving inspection and reducing the effect of personal relationships between inspectors and operators.

The team has also studied the relationship between inspection and production departments in a number of firms. Where inspection is regarded as a specialist function distinct from production, there appears to be a striking similarity of hostile attitude held by operators towards inspectors and vice versa.

Other findings suggest that, before blaming individuals either for inefficiency or for friction between them, as is so often done, it is essential to examine the work situation to see how far the organization is responsible.

II. STUDIES IN SOCIAL ORGANIZATION AND HUMAN RELATIONS

The research described so far can show what a man is capable of doing, but this does not mean he will always do it. Temperament affects his performance, especially in relation to the responsibility involved. So does the influence of family, friends and fellow workers. Much useful research has been done, therefore, on what motivates people in industry and on how various kinds of incentives can affect them.

The value of this work lies not so much in the details of the findings, but in the demonstration of a need for a broad approach to many human problems in industry.

It is easy to think of human relations in industry as being a matter of 'personalities'. When individuals get on with each other there is harmony; where they do not friction results. There is some truth in this, but it is not the whole truth. Research is gradually revealing patterns in human relations that themselves make for harmony or discord. It is also beginning to show how the organization of a factory can affect both the pattern of human relations and the efficiency of its operatives.

A good example comes from a Manchester University study of the so-called 'restriction of output' by workers and the effectiveness of financial incentive systems. While responsible employers would probably dismiss the extremist view that workers want to earn as much money as possible for the least amount of work, perhaps few are aware of the complexity of this type of problem. The research team points to the following factors which may affect the success of incentive payment systems as a means of increasing production: variations in flow of materials and in products, problems of setting comparable rates for different jobs, stability of weekly wage packets, the social characteristics of the employees, local standards of living, trade union organizations, the history and prospects of the industry, and the state of the market for its products.

Many other questions of this kind attract attention. For instance, what impact does technical change make on the organization and structure of a firm and on human relations within it?

What lessons can be learnt from firms' policies for recruitment, training and promotion of personnel at all levels? What special problems arise in employing certain groups, like married women and older people, and how can they be overcome? How can the machinery for handling disputes, grievances and suggestions for improvement be made more effective? How can work be made more satisfactory, and pride in team work fostered?

There are no known laboratory techniques for the study of these problems and so research workers have to rely for the present on less refined methods. One is the case study: a problem is investigated in one or a few factories where this situation is thought to be typical or of particular interest. Such a study cannot reach conclusions of general validity, but it can suggest hypotheses for testing in other situations. Another method is the sample survey, designed to provide statistical information on a wider scale fairly quickly and within specified limits of error. A third technique is interviewing. People in industry are encouraged to talk freely but systematically on a number of relevant topics and the material is then carefully analysed in much the same way as an archaeologist or geologist sorts out his tangled evidence from below the ground.

These methods tend to be slow and often do not yield such clear and positive results as can be obtained in the laboratory. But when well done, they can do much to increase understanding of the complex societies that exist in industry. A few examples of such studies are given here—in some detail, because it is impossible to do justice to any of them in one or two paragraphs. Like the examples given on pages 6–10, they are all drawn from the programme of work sponsored by DSIR and the Medical Research Council in the 1950s.

ORGANIZATION AND PRODUCTION

Studies concerned with the relationship of company organization to industrial production methods reveal a relationship between aims, technology and organization, so complex that no one method of organization can be advocated for companies employing different production techniques, or selling to different markets, or even for the same company at different stages of development.

Nevertheless they consistently indicate that each production method has its appropriate organization and that deviation from that organization, whether due to conscious managerial policy or to unplanned upheavals caused by changing techniques, is likely to be associated with inefficiency and unhappiness.

A major study of this relationship was undertaken at the South East Essex Technical College, which surveyed 100 local firms employing more than 100 people. The firms were first classified as having average success, or above or below average, in terms of their profitability, market standing, rate of development and future plans. The team looked at the firms' organization, to see if any one pattern appeared particularly related to success. They found that successful firms showed great differences in organizational structure, and that these differences related not to obvious factors, such as size of industry, but to the technical complexity of the firms' production system. There appeared to be a pattern of organization common to firms at different stages of technological advance, from unit production such as bespoke tailoring, through batch to mass production, and beyond mass production to process production (petroleum, pharmaceuticals etc.), so that successful firms tended to approximate to the common pattern for the particular stage they had reached, while unsuccessful firms tended to deviate from it.

Some general trends in organization paralleled the increases in technical complexity right up to process production. For example, the team found that, as techniques became more complex, both the number of levels of authority in the organization and the chief executive's span of control increased. Chief executives took fewer but more important policy decisions, which committed the company for increasing lengths of time. Policy decisions were more clearly distinguished from problem decisions, and were increasingly based on an analysis of known facts, rather than on value judgements.

Several trends were observed to increase with every stage from small unit production, through batch production, up to mass production—but no further. Examples are the foreman's span of control, the amount of written communication within the company, and specialization in management functions. Each technical advance made precise control of production more important, and, up to the stage of mass production, firms achieved this precision

with the aid of more and more specialist managers and departments. In process production, however, some of the specialist skills have to be built into the machines in the form of immediate automatic adjustments, and others have to be shared by many line managers.

ORGANIZING TO MEET NEW CIRCUMSTANCES

The study just quoted was not concerned with the ways in which firms change their techniques to meet new circumstances. But Edinburgh University conducted a detailed survey of several English and Scottish firms, in order to discover their ways of responding to the challenge of potentially vast new markets. These firms were either new to the industry or had previously worked on Government contracts and were seeking to develop markets for electronic products and to establish themselves with domestic and commercial consumers.

Working for the Government had involved a very close relationship between designer and user, in which the user was the dominant partner. Not only were Government requirements specific, but Government laboratories might often supply the information which the firm needed to meet them. A firm could be so helped and protected in this way that it could become unfit to deal with other markets. In fact some firms had even had to learn the need for market exploration and development, and then to create departments for these tasks. They moved from a situation where the emphasis was all on development to one where sales were pre-eminent.

Three firms sold radio and television sets to domestic consumers. This market is highly competitive but the consumer buys very largely on price and appearance. The research worker found that the two firms which were developing this market most successfully had adapted their whole organization in the light of this fact. In both of them the directors and chief executives met weekly to determine sales policy, and the crucial decisions about designs and production programmes were taken at these meetings. The meetings formed part of a network of regular consultation throughout each firm, and senior men saw awareness of the market as a major part of their job.

The third firm was commercially less successful than the other two, and behind this fact lay an organization in which sales and design were separated. In this firm, the chief television designer did not attend the sales meeting, and the designers had no means of meeting the dealers. Trade reactions were interpreted solely from sales figures.

In the commercial market demand and financial rewards alike can fluctuate considerably. For firms used to Government work this was a new experience. They also had to deal with customers who might express needs rather than precise requirements, and their needs had to be interpreted by the firm in terms of available techniques, or even sometimes to be developed by explaining the potential value of electronics. The firms had to develop both traditional sales departments and new teams of technical salesmen. They met this situation in various ways. Some transferred technical staff to sales work, a method which depleted their laboratories and eventually frustrated the transferred engineer. Others created a large sales organization divided into product groups, each group being served by its own development/design laboratories. This method seemed generally to encourage major conflict between salesmen and engineers for control of patronage. More successful was the appointment of a development/design engineer with responsibility for exploring the market for all new ideas formulated in his field. Another successful aid was the development of a technical section to analyse technical, industrial and market trends and to make forecasts. This enabled the sales department to co-operate by supplying essential information, instead of competing for control in policy making.

Besides these specific findings, the study raised some more general points about organization. The research team contrasted two types of managerial structure, calling them 'mechanistic' and 'organic'. Organic structures were characterized by a vague definition of roles and responsibilities, much consultation and free contact between individuals, and decisions based on discussion of the facts of the situation.

In the rapidly changing commercial and technical world of the electronics industry these organic structures appeared more effective than the mechanistic. Many concepts of good management—such as division into specialist functions, the idea that the departmental manager should be self-reliant and the idea of

reducing skill at operative level—all directly hindered the free communication of information which seems essential to success in a highly experimental, highly changeable situation. Yet where free communication is so important, specialization and scheduling must be reduced. Essential expertise must be shared by all departments. One manager pointed out that operatives in electronics work were often asked to perform highly-skilled jobs and could contribute vitally to discussions of production methods. In this new field operatives might develop a relationship with production managers similar to that between model-shop craftsmen and development engineers.

Circumstances and personalities contributed to the successful evolution of an 'organic' structure. Thus it developed most naturally in small firms where a high proportion of the personnel had been there 'since the beginning'. It was greatly facilitated by an appropriate style of behaviour set by the chief executive. He could do much to establish the easy, informal relationships which encouraged communication.

PLANNING FOR CHANGE

In order to plan an appropriate organization it is clearly important to anticipate the implications of change, whether in markets or production methods.

These firms were moving into so new a field that sound anticipation was perhaps impossible for them. Nevertheless, the survey of their methods of adaptation produced comparisons which might usefully guide firms in similar situations. For example, some of these firms were mechanical and electrical engineering concerns, which had grafted electronics on to their established work. This process presented the company personnel with particular difficulties. Men who for decades had been authorities in the organization were faced with the introduction of an important new development, the skills of which they might be unable to master.

One aspect of this problem was the commonly difficult relationship between design/development groups and production engineers. The production engineers' training had not equipped them to handle electronics designs, and design departments

complained that the production departments mis-read simple designs, were unable to detect the most obvious errors, insisted on extremely detailed instructions and disliked handling small or unusual jobs. Production engineers produced countercharges, which amounted to complaints that the design departments did not try to understand production problems. Much of the traditional training in production engineering seemed inappropriate to electronics, and quite new production engineering techniques were needed to meet the new circumstances.

A common solution was to introduce a number of liaison officers to explain one department to another. Such interpreters could quickly multiply and their employment seemed to encourage local rather than company loyalties and to reduce the sense of involvement in the company's work and purpose. In general, the firms with fewest intermediary links between development and production worked best.

The other studies were particularly devoted to aspects of planning for technical change. Cambridge University studied the effect of replacing non-automatic by automatic looms in a textile mill and compared this changing process with the situation prevailing in another textile mill, which had changed to automatic looms four years previously. Liverpool University studied the effects of introducing several big technical changes into a large steelworks.

The findings were in several ways similar to those of the Essex and Edinburgh studies. Thus, in the textile mills the technical change altered the status of many jobs, but neither the managers nor the operatives concerned were prepared to recognize the alterations, and traditional relationships persisted long after they had ceased to be meaningful.

In the steel works, the change to continuous rolling made the production units closely interdependent. The company had, on the one hand, to maintain a steady flow of material through them and, on the other, to handle a variety of orders. It had to meet new demands for special steels and to handle engineering problems arising from the construction of new plant. These and other needs led to the creation of many specialist managerial departments. The specialist departments had to be staffed by adequately-qualified people and their functions had to be co-ordinated.

Other changes, such as the installation of a continuous strip mill and the building of a new open-hearth melting shop, raised problems of redundancy. Again, just as the numbers of specialists increased in the ranks of management, so the numbers of craftsmen increased among operatives and brought about changes in the distribution of the labour force.

Any one of these far-reaching changes might have led to unrest and inefficiency. In fact, they did not, and the Liverpool team was interested in how the company avoided a major crisis and the general principles which its methods might imply.

They found many factors contributing towards tranquil change. One was that the alterations were gradual. For various reasons the company had ten years in which to assimilate the idea of continuous rolling, and when the new mill was built transfers of men were made over a long period. Again the company had a history of successful negotiation with the union, with both sides agreed on each other's rights and duties. The unions conceded management's right to install new plant, and management conceded the unions' right to help in arrangements for promotion and transfer. Finally, economic factors helped. The company was able to pay high wages, and the new rates and conditions introduced with the new plant were broadly favourable to most groups.

The Tavistock Institute of Human Relations investigated the consequences of changes in methods of coal-getting. Prior to mechanization the responsibility for the complete task lay with a small working group of about three or four experienced men and their assistants. The new method extended the total work cycle over three shifts. It was found that the workers failed to feel responsible for the completion of the whole task or even to the workers on other shifts, whom they never met on the job. The introduction of the new technique did not achieve the expected increase in production. It has been suggested that this failure was due to the demands of a complicated and rigid work cycle—a system of organization not welcomed by the independent-minded skilled collier.

Such findings may not be startling, but they contain lessons which are not always learned. Not every company can command prosperity and good industrial relations at the same time, but most can ensure that change is gradual, that it is made in

consultation with the unions and that it does not spell hardship for employees. To ensure that the new organization is appropriate not only to the demands of the technology but also to the facts of social life requires skill and thought of a special kind.

III. PROBLEMS AND PROSPECTS

The studies described here, though illuminating and very often pertinent to the circumstances of particular companies, are still only pioneer studies—so much so that any reader with industrial experience is likely to find that they provoke in his mind even more questions than they answer. Thus it may seem to him obvious that a company's organization should be carefully related to its purpose, its technology and its circumstances. He may be interested in the comparisons which have been drawn on these lines; but very likely he will want to see the work extended, because he has direct experience of organizations which do not compare with those included in the surveys.

For instance, many of the studies describe disturbance and unhappiness which may result at all levels in an organization because technical or other changes have brought with them unrecognized changes in individual function and status. Their lessons are that these aspects of change need more careful study, and that people need to be prepared for change by consultation, by safeguarding their interests and by training.

Training is not a new idea for industry: it is an accepted activity in most large companies. But what training is thought to be appropriate for adapting a foreman used to quiet life to a job full of tension? Or for teaching an operative a new outlook on his job and his responsibilities? Or for preparing a self-reliant manager for work requiring painstaking consultation? Why is such training thought appropriate? What evidence is there that present training schemes achieve their purpose? What facts have been gathered on which to base these new developments in training? What facts still need to be collected?

Again, the growing demand for intellectual ability in senior posts in industry, which these studies amply confirm, poses several problems. Already, many companies take on management trainees so as to discover this essential ability early and develop it in good time. But it cannot be said that management trainees have been generally popular figures, that they have always fulfilled the expectations placed upon them. What is the best way of bringing ability into an organization? The Acton Society Trust carried out a survey of how some 50 large firms in this

country recruited and trained potential managers. While there is obviously no single policy which is both guaranteed to attract people of ability, and suitable for all companies, the survey points to certain essential requirements, such as adequate incentives and prospects, opportunities to exercise initiative, and sustained interest by senior managers in the development of good subordinates.

Problems of recruitment and selection lead back to problems of general education. To what extent do people in industry and the world of education uphold different values in our society? How far are these views complementary and how far in conflict? What has been the effect of collaboration, where attempted, between large companies and academic institutions?

Many other social and industrial problems are implied in these studies. Shift work, for example, may well become the norm of the future. What will be its effects—on families, retailers and those who provide transport and power? Can social investigation help here?

More needs to be known too about problems of redundancy and social mobility of labour. What incentives make people mobile? Why are some people at some levels in industry so much more mobile than others? Some objective analyses of the effects and implications of temporary redundancy might greatly help management/union discussions on the subject.

THE PROBLEM OF COMMUNICATION

If it is agreed that this type of study has value today, and may be essential tomorrow, what must be done to ensure that the new work is undertaken? The first step must be to promulgate the findings of studies already completed. But how is this to be done? What sources of information do executives rely on? This is in itself an important subject for study, and researches to date have provided only piecemeal, though interesting, answers. It seems that it may be very difficult indeed to introduce information into some companies, whose executives rely on experience more than reading or technical training, and whose outside contacts are limited virtually to customers and suppliers.

The first need, fairly obviously, is for clear and sensible reporting, whatever the length and technical difficulty of the

material. This is because research results in much of this field have to be presented almost entirely in words: success in communication therefore depends very much on the right choice of words, the right arrangement of a report and above all clear thinking. Not all research workers can be expected to master narrative and style, though they ought at least to show interest in this side of their work. They must, however, be able to think clearly and to judge which of their findings have practical importance and which of them only confirm with objective evidence what is already widely accepted in industry as true.

Even if all this is done, a research report is likely to be too long and too littered with technical concepts and language to be thoroughly read by more than the few people in industry who have been trained to think in these terms. Various 'industrial versions' of the reports are needed—articles in suitable journals and perhaps a short booklet bringing out the main findings of the study and their implications for industry as a whole. It is a common practice for a senior executive to commission such a summary from a junior colleague whenever he hears of a report that interests him. DSIR has tried with some success to perform that function in a general way, preparing 30–40 page industrial versions of the most suitable of the reports which it has helped to sponsor. It has experimented with different forms of presentation and has used professional writers with knowledge of this field, as well as the research workers themselves.

This exercise has not been so simple as it sounds, chiefly because many of the research results require a good deal of interpretation before they can be presented simply to a lay audience. But this very difficulty has made it a more useful exercise than was originally expected, since it means that every conclusion has to be thought out and its implications carefully weighed. In some cases, especially when no comprehensive report has been written for publication, the exercise has been necessary to determine precisely how useful the findings are likely to be for industry.

The written word, however, is as limited a tool of communication in the human sciences as it is in the natural sciences and technology, and other methods must be given every possible trial. One likely method is for interested national organizations to hold meetings and conferences at which research workers discuss

their findings with representatives from industry. DSIR has organized several of these and found them very useful. Another is for research workers to give help direct to organizations interested in applying the results of their studies. But both these methods take up time that is badly needed for further research. A third method, with wider possibilities, is to use research results in training courses for managers and supervisors; but this must be based initially on written reports or on conferences with research workers. Finally there is the possibility of spreading knowledge indirectly through consultant specialists.

DSIR is keeping, at the Warren Spring Laboratory, a continuous record of research in progress in the human sciences so that up-to-date information is available to research workers and other interested people.

In the past some industrialists have criticized work in this field for being trivial or about the wrong subjects. In recent years this criticism has been met by encouraging industrial organizations to come forward with their ideas for research, and to name subjects which should be given priority. DSIR in particular has found collaboration of this kind very useful. But it runs into unavoidable difficulties. Industry can say what its problems are but it cannot suggest what sort of research programme is likely to throw up solutions, nor can it really determine which problems are fundamental and which derivative. Least of all can it formulate an individual research project precisely. The art of collaboration is to find out first what industry would like to have investigated, and then to help research workers formulate their projects and build up a research programme. Small working groups and conferences seem to be the best way of doing this.

There is much a director or senior manager can do to foster research in the human sciences once he becomes convinced of its value to people like himself. He can talk about it and encourage others to read and hear what he has read and heard. He may find it appropriate to set up a human sciences department within his own organization, and to help its staff to gain general acceptance and to protect them as far as possible from pressures of time and politics. He may invite the members of independent research institutes to come and discuss their work or to help apply it to his company. He can encourage his research or trade association to undertake work in this field, pointing out that the British Iron

and Steel Research Association and the British Boot, Shoe and Allied Trades Research Association have done just this already out of their own funds. Finally, he can allow independent research workers to carry out investigations within his own organization giving them the open support which can help them gain the interest and co-operation of his staff.

The role of consultant specialists has been very briefly mentioned. Apart from offering advice on selection, training and methods of work and payment, consultants could well extend themselves to cover not only problems of fitting the job to the worker by the application of ergonomic principles to the design and operation of individual machines, and of new plant and processes, but also the social implications, both inside and outside the firm, of innovation in the work situation. He might, in fact, provide a useful link between the research worker and the factory.

PROBLEMS OF PERSONNEL

All this endeavour will be of little avail unless there is an adequate supply of trained research workers. At present these specialists are extremely scarce, mainly owing to the lack of reasonable career prospects. While there are a number of short-term grants which enable recent graduates to gain experience of research, there are very few permanent research posts offering security and status of the kind that will persuade senior scientists to give their whole time to research. Small research teams are usually attached to university departments under the supervision of faculty members for a specified period. If a director of such a group leaves the department—perhaps to take a more remunerative post in industry—the group may well break up despite all the effort put into its creation. For long-term research in the human sciences, as in other fields, it is essential to create a number of stable research groups of viable size. This will mean a higher ratio of senior to junior staff than at present, so as to ensure continuity of direction if one or more seniors leave the group, and also to guarantee adequate training and supervision of junior research workers. Such an aim can only be achieved if financial support is given to research in the human sciences on a permanent and large enough basis, not least in the new colleges of advanced technology where psychology and physiology departments can

best develop in close association with engineering and other technologies. While the universities and colleges are responsible for forming these groups, mainly out of their general funds for teaching and research, industry can help to make them stable by financing some of the necessary senior posts—professors, readers and directors of research—and by endowing a number of senior and junior fellowships to be held for limited periods in specified fields. Support of this kind would supplement assistance already provided by DSIR and the Medical Research Council for the training of research workers and for special researches.

THE FUTURE

As knowledge of this research spreads, as interest in its findings grows, and as the relevance of this work to industrial problems is widely recognized, it is likely that industry will undertake more of its own research. At the same time industry is likely to give more encouragement, in terms of finance and facilities for research, to the universities and other independent research bodies. If the research is to result in action, it must spring from both sources, and not mainly from the latter as at present. The independent bodies will then concentrate their interest on general principles and company departments will apply these principles and study the special problems of their own organizations.

Most of the pioneering studies reviewed here are partly general and partly applied; but they demonstrate why both types of research are necessary. With few exceptions they have been conducted by independent research bodies, which have analysed a particular problem or aspect of industry in several (or even many) different companies. Thus the findings take the form of general observations and principles. It must be quite fortuitous if they apply in all respects to any one company, and no executive can assume that they do. Indeed, in order to advance our knowledge, it is essential for independent research workers to have opportunities to carry out studies within industry, which may have no immediate practical value. For it is only from these long-term projects, involving a representative sample of a number of different firms or even industries, that general principles or theory can be formulated.

But these surveys achieve much that could not be achieved by

specialists in the human sciences working in the employ of a particular company. They distinguish permanent and important aspects of a subject from those of temporary significance only. They may sufficiently isolate some features (for example, of human perception or learning) for them to be studied usefully in a laboratory. They share these advantages with all other researches in any field conducted by independent bodies.

Other advantages, however, are particularly important for research in human sciences. One of these is freedom from political pressure. Research workers in independent institutes do not have to please management, or trade unions or the Government. Another advantage is that an outsider can often achieve an unbiased understanding of the changing needs of the company (or companies): understanding which, for one within the company, would demand almost superhuman qualities of objectivity, personal courage and insight. It is thus quite unreasonable to expect all the information for decisions affecting organization and personnel to come from within the company itself.

Above all, this kind of research has a cumulative long-term value. In the human sciences it is necessary to build up a fund of knowledge from the relatively small contributions of each study—not a set of formal rules or mathematical formulæ, as in the natural sciences, but a classified store which, as it grows, gives a greater insight into many human and organizational problems facing industry and a better chance of solving them satisfactorily. Then problems will not appear peculiar to one firm or one group of people, but will exhibit characteristics already observed elsewhere, though probably not in the same combination. If what has been achieved so far leads industry to enlarge its interest in the human sciences and to co-operate in more research projects, this will encourage more research workers to devote their energies to investigating industrial aspects of human performance, and so, in turn, to providing more results which can be applied to problems in industry.

To sum up, then, the next step is for the accumulated research findings to be translated to fit each company's circumstances, and applied study of this kind is best done by a specialist working temporarily or permanently with the company, even if an independent research worker gives advice from outside. In the long run, a division and balance between long-term and *ad hoc*

research is likely to emerge, and it is vital for both industry and research workers that this should be so. The long-term work will be concentrated in bodies of university standing, the applied work in private companies, research associations and other industrial organizations and in technical colleges.

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